Performance Evaluation of DTN Routing Protocols in Vehicular Network Environment

Yongliang Sun[1,2(✉)], Yinhua Liao[1], Kanglian Zhao[2], and Chenguang He[3]

[1] School of Computer Science and Technology,
Nanjing Tech University, Nanjing, China
syl_peter@163.com

[2] School of Electronic Science and Engineering, Nanjing University, Nanjing, China

[3] Communication Research Center, Harbin Institute of Technology, Harbin, China

Abstract. Compared with the traditional Internet architecture, Delay/Disruption Tolerant Networking (DTN) has a bundle layer between the application layer and transport layer and is able to tolerate delays and disruptions. In this paper, we simulate typical DTN routing protocols and configure a vehicular network environment to evaluate the protocol performance. We compare the performance evaluation indicators that include delivery ratio, overhead ratio, average delay, and average buffer time with different node numbers and buffer sizes. We finish the simulation using Opportunistic Network Environment (ONE) simulator and the DTN routing protocols are evaluated according to the simulation results.

Keywords: DTN · Routing protocol · Vehicular network
Performance evaluation · ONE simulator

1 Introduction

Currently, vehicular communication technology has been a research hot-spot of automotive industry. In vehicular environment, vehicles are usually equipped with short-range wireless equipments in order to communicate with other vehicles or roadside infrastructures, so the communications of vehicular network can be used for different applications and services. With the development of Vehicular Ad-Hoc Network (VANET) [1], it is necessary for vehicles to transmit collected information at any time. Although traditional Internet protocol is very mature and many routing protocols have been proposed, VANET is different from traditional network. Vehicles may move at a fast speed on the road and road topologies are various that may lead network delays, disruptions and other problems. Because of the facts mentioned above, a better solution is needed and therefore the emergence of Delay/Disruption Tolerant Networking (DTN) has attracted intensive attention [2].

DTN is a new emerging network architecture in recent years. It is used to solve the problem that is frequent network disruptions due to node movement

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and sparsity distribution [3,4]. Thus, DTN has been applied to VANET. Messages can be stored, forwarded and then delivered to the destination node finally. In order to transmit messages effectively, nodes may follow some routing protocols so that they can cooperate with each other and achieve a better Quality of Service (QoS).

In this paper, we evaluate six typical DTN routing protocols in a vehicular network environment and draw some valuable conclusions. The simulation platform is Opportunistic Network Environment (ONE) simulator [5], which is designed for DTN environment simulation. It integrates movement models, DTN routing protocols and visual graphical interfaces, so ONE is a powerful simulation tool. We select a specific map through the OpenStreetMap [6] and configure the simulation scenario to make it approximate to a real scenario. Then we evaluate the performance of the six typical DTN routing protocols with different node numbers and buffer sizes.

The remainder of this paper is organized as follows: Sect. 2 introduces the related works including traditional routing protocols and DTN routing protocols. The performance evaluation indicators that include delivery radio, overhead ratio, average delay, and average buffer time are described in Sect. 3. Section 4 gives the details of simulator parameter configuration and evaluates the performance of typical DTN routing protocols. Finally, Sect. 5 concludes this paper.

2 Related Works

Recently, researchers make great efforts to deal with collaboration communications between mobile nodes, so many routing protocols have been proposed. For example, Geographic Source Routing (GSR) protocol is one of them [7]. It abstracts map topology data and uses the road intersections as anchor nodes. Then it calculates the shortest path from the source node to the destination node with Dijkstra algorithm. Messages are forwarded along the selected anchor nodes. Improved Greedy Traffic Aware Routing (GyTAR) protocol [8] dynamically selects anchor nodes for forwarding messages according to real-time node density. Through considering neighbor node velocity, the neighbor node is exploited to carry and forward messages at the next moment. Another protocol is called Adaptive Connectivity Aware Routing (ACAR) protocol [9]. ACAR selects the optimal path for forwarding messages based on Global Positioning System (GPS), electronic map and so on. However, these routing protocols have their limitations. Thus, considering the advantages of DTN, researchers apply several DTN routing protocols to VANET as follows:

A. *Epidemic*
Epidemic routing protocol is based on flooding strategy [10]. When two nodes meet each other, they exchange messages. After exchanging the messages multiple times, each non-isolated node will receive all the messages.

B. *Spray and Wait*
Spray and Wait routing protocol is also based on flooding strategy [11]. The routing protocol has two phases: spray phase and wait phase. In the spray

phase, messages of the source node are spread to neighbor nodes. In the wait phase, if the destination node is not found in the spray phase, then the messages will be passed to the destination node by Direct Delivery algorithm.

C. *First Contact*
First Contact routing protocol is based on forwarding strategy [12]. In the transmission process, only one message copy of each message is transmitted in the network. In the First Contact routing protocol, source node will send the message to the node that it first meets.

D. *Direct Delivery*
Direct Delivery routing protocol is also based on forwarding strategy [5]. Different from First Contact routing protocol, the source node will keep the message until it meets the destination node and then the message is transmitted.

E. *Prophet*
Prophet routing protocol is based on probability strategy [12]. The protocol defines a transmission prediction value to describe the probability of successful transmission between nodes. When two nodes meet, the two nodes update the transmission prediction values and then decide whether to forward the messages or not.

F. *MaxProp*
MaxProp routing protocol is based on scheduling strategy [12]. This protocol sets priorities for messages. When two nodes meet, messages are transmitted according to the priorities. The messages with low priority are less likely to be transmitted, which makes the protocol more effective.

3 Performance Evaluation Indicators

We simulate these routing protocols under a vehicular network scenario, through which these routing protocols are compared and analyzed. There are many factors that can be used for evaluating routing protocol performance. In this paper, the routing protocol performance is evaluated through comparing the following four indicators:

A. *Delivery Ratio*
Delivery ratio is the success rate of transmitting messages, which indicates the ratio of the total number of messages arrive at the destination node to the total number of messages transmitted by the source node in a certain time period. This indicator describes the ability of the routing protocol to forward messages correctly to the destination node.

B. *Overhead Ratio*
Overhead ratio refers to the ratio of difference between the messages that arrive at the destination node and forwarded messages to number of the messages that arrive at the destination node in a certain period of time. High overhead ratio means that a large number of messages are forwarded, which will increase the collision probability and energy consumption.

C. *Average Delay*
Average delay is the average time that the messages arrive at the destination node from source node. Small average delay means strong transmission capability, high transmission efficiency and low network resource occupation.

D. *Average Buffer Time*
Average buffer time is the average time that messages are stored in the node buffers. It is generally measured for performance evaluation.

4 Performance Evaluation of Typical DTN Routing Protocols

The map of downtown area in Nanjing City is selected in this paper, which is shown in Fig. 1. The DTN routing protocol simulation is performed using ONE simulator and the simulation interface of ONE simulator is shown in Fig. 2. With different node numbers and buffer sizes, the performance evaluation indicators that are delivery ratio, overhead ratio, average delay, and average buffer time of the six DTN routing protocols are obtained and compared.

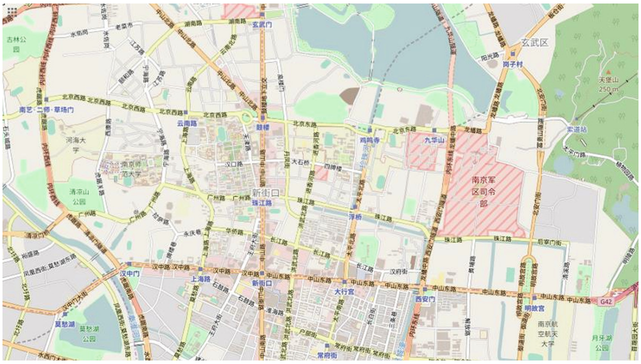

Fig. 1. Road topology map of Nanjing downtown area.

4.1 Node Number

We compare the performance of six typical DTN routing protocols with different node numbers. In order to make the simulation approximate to a real scenario, we mainly set four node types that are bus, taxi, car, and people with a ratio of 1:4:10:25. The simulator parameters are shown in Table 1.

The number of nodes varies from 80 to 280 and the simulation results are shown from Figs. 3, 4, 5 and 6. From these simulation results, we can see that the number of nodes has a great impact on the four indicators of these routing protocols. Figure 3 shows that, with the growth of node number, the delivery ratio increases and the impacts on MaxProp and Spray and Wait are significant.

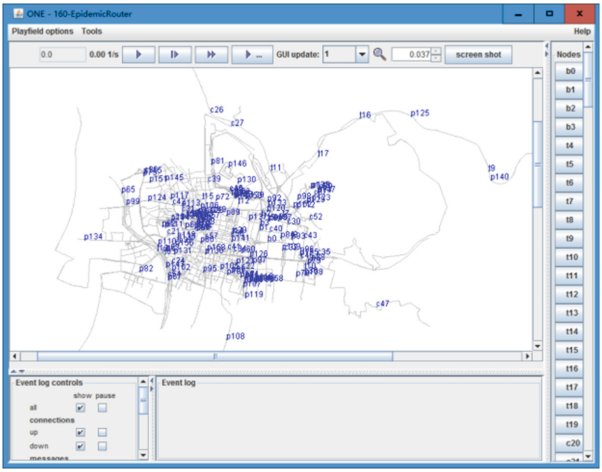

Fig. 2. Simulation interface.

Table 1. ONE simulator parameter configuration with different node numbers

Parameters	Bus	Taxi	Car	People
Number of nodes	2–7	8–28	20–70	50–175
Moving speed (m/s)	2.7–11.1	2.7–22.2	2.7–13.9	1.0–3.0
Buffer size (Mbytes)	8			
Transmission range (m)	10			
Transmission speed (Kbps)	250			
Message size (Kbytes)	500–1000			
Message creation interval (sec)	25–35			
Map size (m)	Width: 35000, Height: 30000			
Movement model	Shortest path map based movement			
Message time to live (hr)	5			
Simulation time (sec)	14400			

In Fig. 4, the network overhead ratios of Direct Delivery and Spray and Wait are independent of the node number while the overhead ratios of the other four protocols raise when the node number increases. Figure 5 shows that the number of nodes has different effects on the average delay. The average delay generally decreases when the node number increases. As shown in Fig. 6, with the growth of node number, the average buffer time of Spray and Wait protocol increases slowly. Regarding Direct Delivery, the upward trend is not obvious. At the same time, the average buffer times of the other protocols slowly decrease.

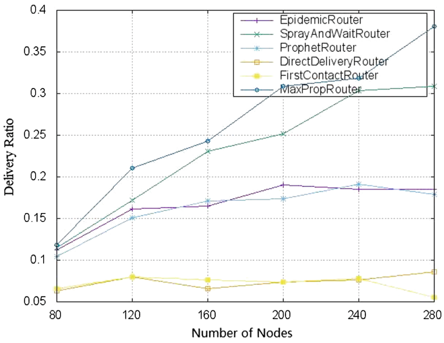

Fig. 3. Delivery ratio vs number of nodes.

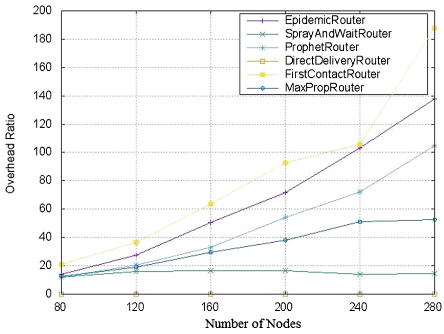

Fig. 4. Overhead ratio vs number of nodes.

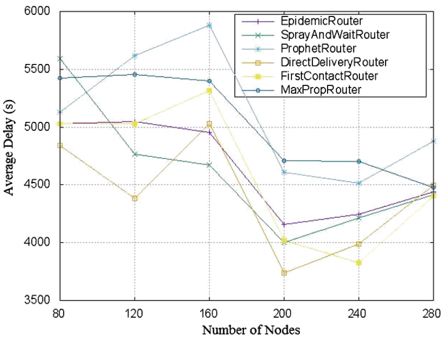

Fig. 5. Average delay vs number of nodes.

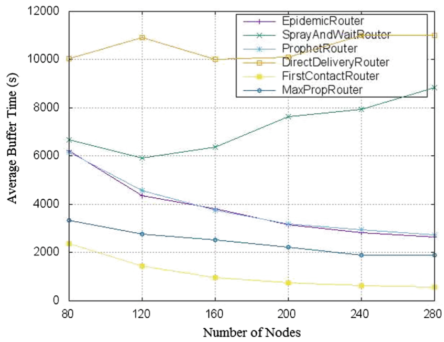

Fig. 6. Average buffer time vs number of nodes.

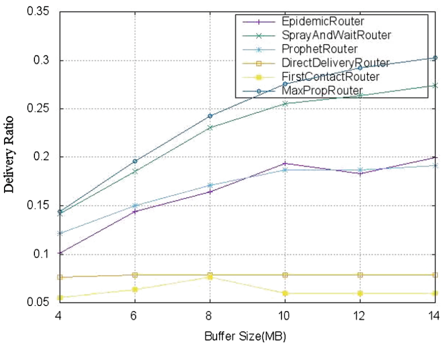

Fig. 7. Delivery ratio vs buffer size.

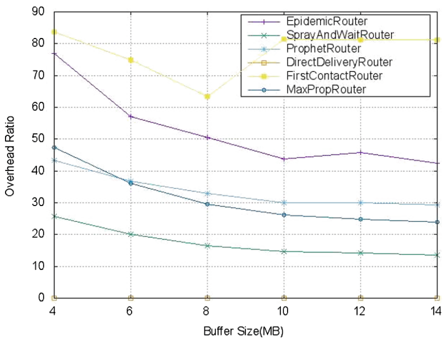

Fig. 8. Overhead ratio vs buffer size.

4.2 Buffer Size

We compare the performance of six typical DTN routing protocols with different buffer sizes. The simulator parameters are shown in Table 2.

Table 2. ONE simulator parameter configuration with different buffer sizes

Parameters	Bus	Taxi	Car	People
Number of nodes	4	16	40	100
Moving speed (m/s)	2.7–11.1	2.7–22.2	2.7–13.9	1.0–3.0
Buffer size (Mbytes)	4-14			
Transmission range (m)	10			
Transmission speed (Kbps)	250			
Message size (Kbytes)	500–1000			
Message creation interval (sec)	25–35			
Map size (m)	Width: 35000, Height: 30000			
Movement model	Shortest path map based movement			
Message time to live (hr)	5			
Simulation time (sec)	14400			

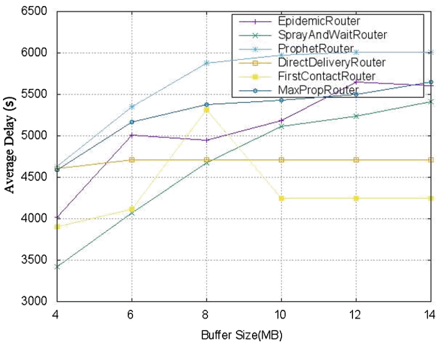

Fig. 9. Average delay vs buffer size.

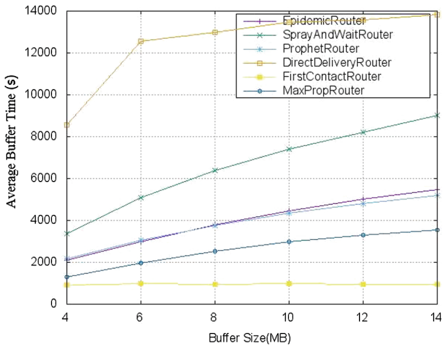

Fig. 10. Average buffer time vs buffer size.

The buffer sizes of the nodes vary from 4M to 14M and the simulation results are shown from Figs. 7, 8, 9 and 10. From these simulation results, we can see that the buffer size also has an effect on the performance of each routing protocol. Figure 7 shows that buffer size has no effect on the delivery ratios of Direct Delivery and First Contact. But regarding the other protocols, the larger node buffer size is set, the higher delivery ratio can be obtained. In Fig. 8, when the buffer size increases, the overhead ratio of Direct Delivery basically has not been influenced and the overhead ratios of other routing protocols have a small downward trend. As shown in Fig. 9, the impacts of the buffer size on the average delays of Direct Delivery and First Contact are not obvious, but a certain degree of transmission delays of the other protocols are caused when the buffer size increases. Figure 10 shows that, with the growth of buffer size, there is no influence on First Contact, the average buffer times of the other protocols increase a little.

5 Conclusion and Future Work

In this paper, through evaluating the performance of DTN routing protocols in a vehicular network environment, some valuable conclusions are draw as follows: (1) the node number and buffer size both have significant effects on the performance of each routing protocol. (2) Epidemic has a poor performance in the simulation. Its delivery ratio is low and transmission delay has no obvious advantages. (3) Spray and Wait has the high delivery ratio and low overhead ratio, so it outperforms the other routing protocols in the simulation. (4) Regarding First Contact, it has low delivery ratio and high overhead ratio, so its performance is generally worse than the other protocols. (5) The overhead ratio of Direct Delivery is closed to 0 with different node numbers and buffer sizes, which make it the best routing protocol among the six protocols in a low energy node scenario. (6) Prophet does not have an outstanding performance in the simulation and MaxProp has a high delivery ratio with different node numbers and buffer sizes.

In the future, we will try more road topologies and analyze the influences of road topologies on the routing protocol performance. Additionally, according to previous research and analysis, we expect to improve an existing DTN routing protocol to achieve a better performance.

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